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Performance and emissions of lemon peel oil biodiesel powered single cylinder direct injection diesel engine loaded with ceria nanoparticles additives and stabilized zirconia coating

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Abstract

The main aim of the present work is to examine the performance and emission characteristics of single cylinder direct ignition diesel engine powered with 3 proportions of lemon peel biodiesel (B10, B20 and B30) using ceria nanoparticles and yttria-ceria-stabilized zirconia as fuel additive and thermal barrier coating (TBC) materials, respectively, using pure diesel as base fuel. From the results of the engine performance and exhaust analysis, the volumetric efficiency and friction power increases whereas specific fuel consumption decreases for coated engine and observed insignificant deviation for CO and CO_2 emissions between coated and uncoated engines. Hence lemon peel biodiesel could be employed in diesel engine with ceria nano particle additive and yttria-ceria-stabilized zirconia TBC.

Introduction

Energy consumption is massive nowadays and a critical aspect of the development of any country. Simultaneously, energy shortage has become an economic risk to national development all over the world. Since the dawn of civilization, the energy demand has been steadily increasing due to population growth and industrial development [1]. Fossil fuels are used as the primary sources of energy to meet demand. However, fossil fuels require replacement because of their resource depletion, elevated gas emissions, and low reliability. Lowering fossil fuel usage and the development of renewable energy supplies can solve energy demand [2].

Internal combustion engines, often known as diesel engines, convert chemical energy in diesel to mechanical energy. It is mainly used for transportation in vehicles and power generation [3]. Hydrocarbons, CO, CO_2, SO_2, NOx, and particulate matter (PM) are the most common exhaust pollutants from diesel engines. They pose serious health and environmental risks to life. However, an alternate option is required for diesel fuel due to enhanced exhaust gas emissions from diesel engines [4].

Alternative fuels are developed to reduce exhaust gas emissions and avoid the depletion of fossil fuels [5]. Biodiesel is an alternative liquid biofuel whose characteristics and performance are identical to pure diesel [6]. Vegetable oils and animal fats are the feedstocks for biodiesel production. In particular, non-edible vegetable oils, used and waste cooking oils are used as limiting reactants for biodiesel production. In addition, alcohol, catalyst, reaction time, temperature and agitation speed play a vital role in yielding maximum biodiesel [7]. Also, engine and ancillary components are undergoing research to regulate exhaust gas emissions. [8].

Fuel additives are added to pure fuel or fuel blends to maintain or improve their properties. In general, metals having lower heat conductivity are a viable option for boosting fuel attributes [9]. Nevertheless, water is also used as a fuel additive to form an emulsion. Due to the presence of water, the density and kinematic viscosity of emulsion fuels rose slightly [10]. The addition of zinc nanoparticles to diesel–pomoplion stearin wax biodiesel blends had no significant influence on fuel characteristics, including density, viscosity, and flash point with the reduction in thermal conductivity [11]. Manganese, cerium, alumina, and silica are the most widely used nanometal additions. The influence of mixing cerium oxide and cerium dioxide on engine performance revealed that adding the nano-additives reduced brake specific fuel consumption, hydrocarbon and NOx emissions while increasing engine power [12].

Engine modification techniques such as thermal barrier coating, fuel preheating, geometry modification, antioxidant usage, etc., are utilized to achieve the rated power output [13]. Thermal barrier coating (TBC) is a ceramic layer applied to engine components to improve heat transfer effects. TBCs have widespread use in jet engines and gas turbines to lengthen component life and maximize engine efficiency [14]. Several research organizations have investigated zirconates as a potential replacement for Yttria-stabilized zirconia (YSZ). Lower sintering activity and low heat conductivity are the primary benefits of some zirconates [15]. Yttria-partially-stabilized zirconia, partially stabilized zirconium, Yttria stabilized zirconia, magnesia-stabilized zirconia, and aluminium oxide are the most often used TBC materials. For greater thermal efficiency, Al_2O_3 has been used to coat blades in diesel engines [16]. When 450 μm thick partly stabilized zirconium coating material was applied on an uncoated diesel engine, it was discovered that the coated engine exhibited a 6% improvement in engine thermal efficiency [17].

The various non-edible oils based on plant sources are reported to produce biodiesel [18], [19], [20]. To the best knowledge of authors, limited literature is available on the utilization of oil or biodiesel produced from lemon-based materials such as lemon fruit, lemongrass, and lemon peel [21], [22], [23], [24], [25], [26], [27]. Cerium oxide nanoparticle is the common fuel additive for proven elevated properties [22], [24], [25], [26]. Zirconia is a common base material for the preparation of TBC material because of its less thermal conductivity. Additional materials added to zirconia in the right proportion enhance heat transfer effects [13], [17], [25], [27], [28], [29]. From the analysis of literature, biodiesel prepared from lemon peel oil in 3 proportions (B10, B20 and B30) is used in single stroke direct ignition diesel engine using cerium oxide nanoparticles as a fuel additive with and without yttria-ceria-stabilized zirconia TBC is investigated in this study to examine the performance and emission characteristics using pure diesel as base fuel.

Section snippets

Materials

Lemon fruits were procured from a nearby vegetable shop in Chennai, India. Lemon peel was collected from the fruits using domestic peeler. The peel was collected and washed with double distilled water to remove contaminants. Then the collected peel was used for oil extraction. Commercial ceria nanoparticles and yttria-ceria-stabilized zirconia were purchased from scientific suppliers, Chennai, India. Ceria nanoparticles were ball milled before use. Yttria-ceria-stabilized zirconia was used…

Preparation of biodiesel

Lemon peel oil and biodiesel were prepared following procedure given in the literature with the minor modifications [23], [29]. Lemon peel oil was prepared from the lemon peel using steam distillation. 1 L of lemon peel oil was preheated to 60 °C and mixed with 2.25 L of methanol (oil to methanol molar ratio of 1:9) and 12.65 g of KOH (oil to alkali mass ratio of 1.5 %). The mixture was heated for 2 h at 720 rpm. The mixture was allowed to settle in separating funnel and biodiesel was collected …

Results and discussion

The lemon peel biodiesel was prepared and tested for conventional properties as listed in Table 2. The results and analysis of engine performance and emission in diesel engine for coated and uncoated ceria nanoparticle amended lemon peel biodiesel blends are discussed in this section.…

Conclusion

This work aimed to examine the performance and emission characteristics of single cylinder direct ignition diesel engine powered with 3 proportions of lemon peel biodiesel (B10, B20 and B30) using ceria nanoparticles and yttria-ceria-stabilized zirconia as fuel additive and thermal barrier coating materials, respectively, using pure diesel as base fuel. Brake, indicated and friction power, brake and indicated thermal efficiencies, volumetric efficiency, fuel and air flow, and specific fuel…

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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